National Renewable Energy Laboratory

A national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy

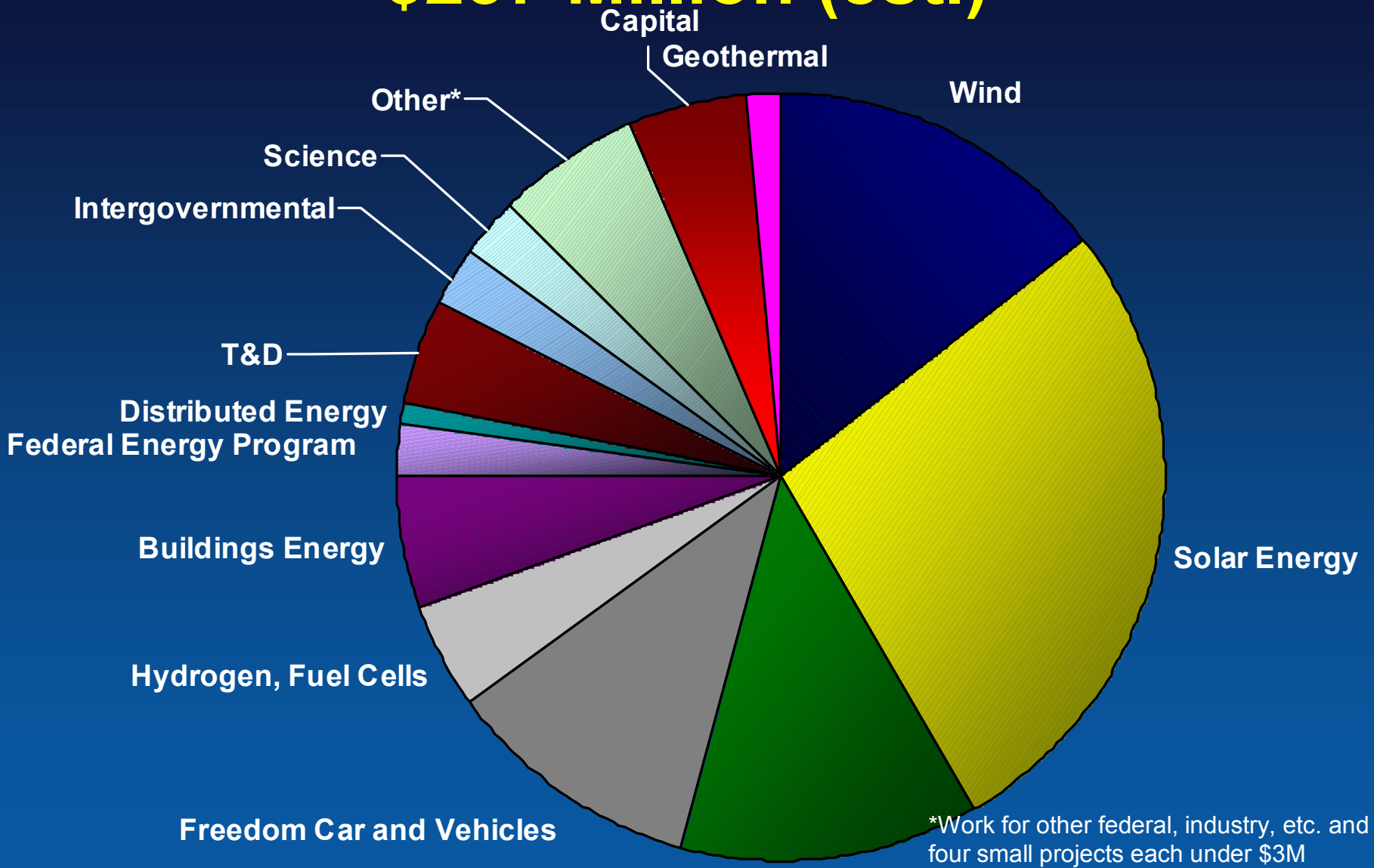
Innovation for Our Energy Future

NREL is operated by Midwest Research Institute • Battelle

National Renewable Energy Laboratory

- ***World leader*** in Renewable Energy and Energy Efficiency technologies
- Only US National Laboratory ***dedicated*** to renewable energy and energy efficiency
- Research spans fundamental ***science*** to ***technology*** solutions
- ***Collaboration*** with industry, university and international partners is a hallmark
- Research ***linked*** to market opportunities

NREL FY04 Funding by Program
$237 Million (est.)



*Work for other federal, industry, etc. and four small projects each under $3M

Updated October 21, 2003

Major Technology Thrusts

Supply Side

Wind

Solar

- Photovoltaics
- Concentrating Solar Power
- Solar Buildings

Biomass

- Thermochemical Processes
- Biochemical Processes
- Integrated Systems

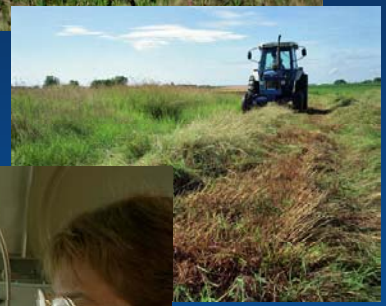
Geothermal

Hydrogen

- Production
- Storage
- Infrastructure & End Use

Distributed Energy

- Distribution & Interconnection
- Thermal Systems
- Superconductivity



Demand Side

Vehicle Technologies

- Fuel Cell/Hybrid Vehicles
- Fuels Utilization

Building Technologies

- Building Efficiency
- Zero Energy Buildings

Energy Management

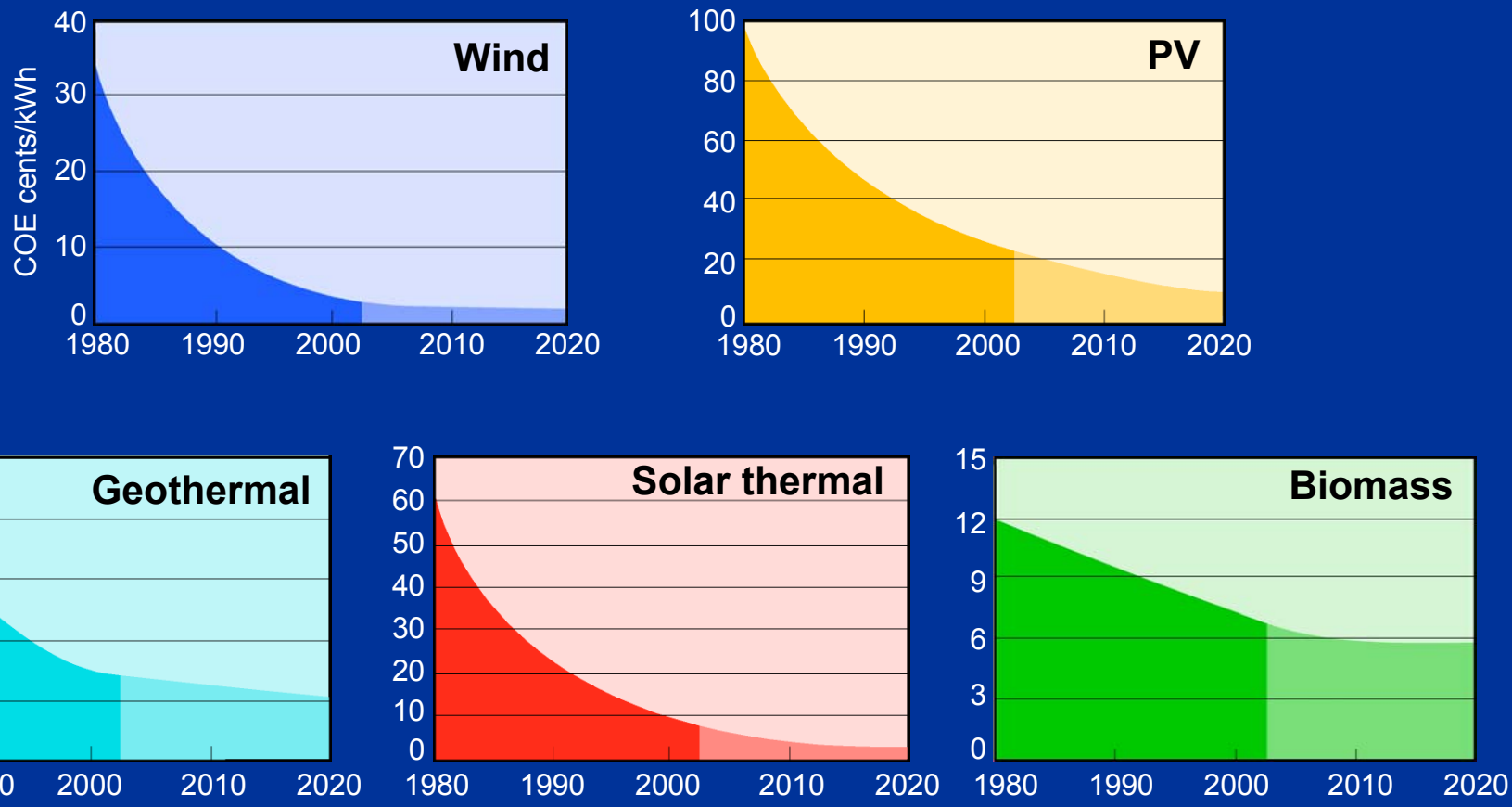
Advanced Industrial Technologies

Crosscutting

- **US and International**
- **Basic Energy Science**
- **Techno-Economic Studies**
- **Education**

Driving Down Renewable Energy Costs

Levelized cents/kWh in constant $ (2000)[1]



Source: NREL Energy Analysis Office

[1]These graphs are reflections of historical cost trends NOT precise annual historical data.

Updated: October 2002

Broadening the Value Proposition

- **Technology Access**
  - •World-leading Resources
  - •Technology Information
  - •Roadmaps, Performance Data
- **Prototyping, Scale-up Engineering, Field Testing**
- **Market Analysis**
  - •Techno-Economic and Life Cycle Assessment
- **Start-up / Business Incubation Support**
  - •Venture Development, Forums
- **Partnership Creation**
  - **•Alliance Building**
  - **•Technology and Market Channel Partners**
- **Access to Funding / Risk Capital**
- **Emissions Trading / Opportunity Awareness**
- **Connect to Policy Framework and Incentives Access**

Low Thermal Resistance IGBT Structure

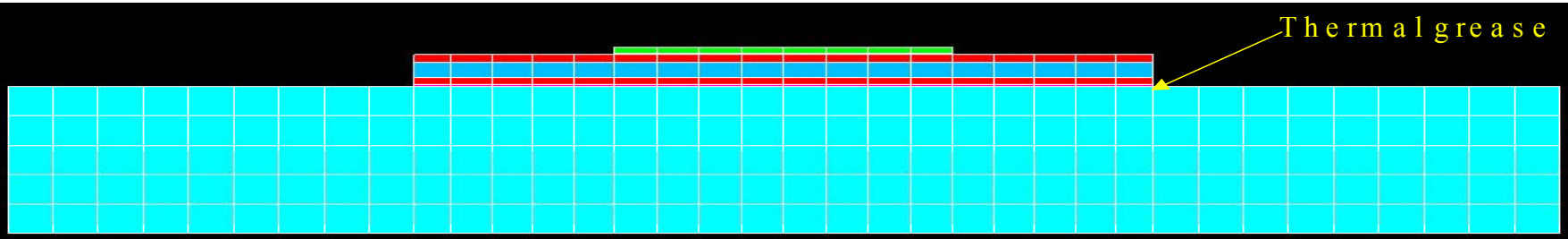
- NREL researchers have developed power semiconductor modules (IGBT) with significantly improved cooling.

- The improvements can help solve the heat dissipation problems caused by higher power, smaller modules.

- They are used in automobiles, hard drives, data storage devices, nearly any electronic product.

Low Thermal Resistance IGBT Structure

Cross Section of IGBT Considered



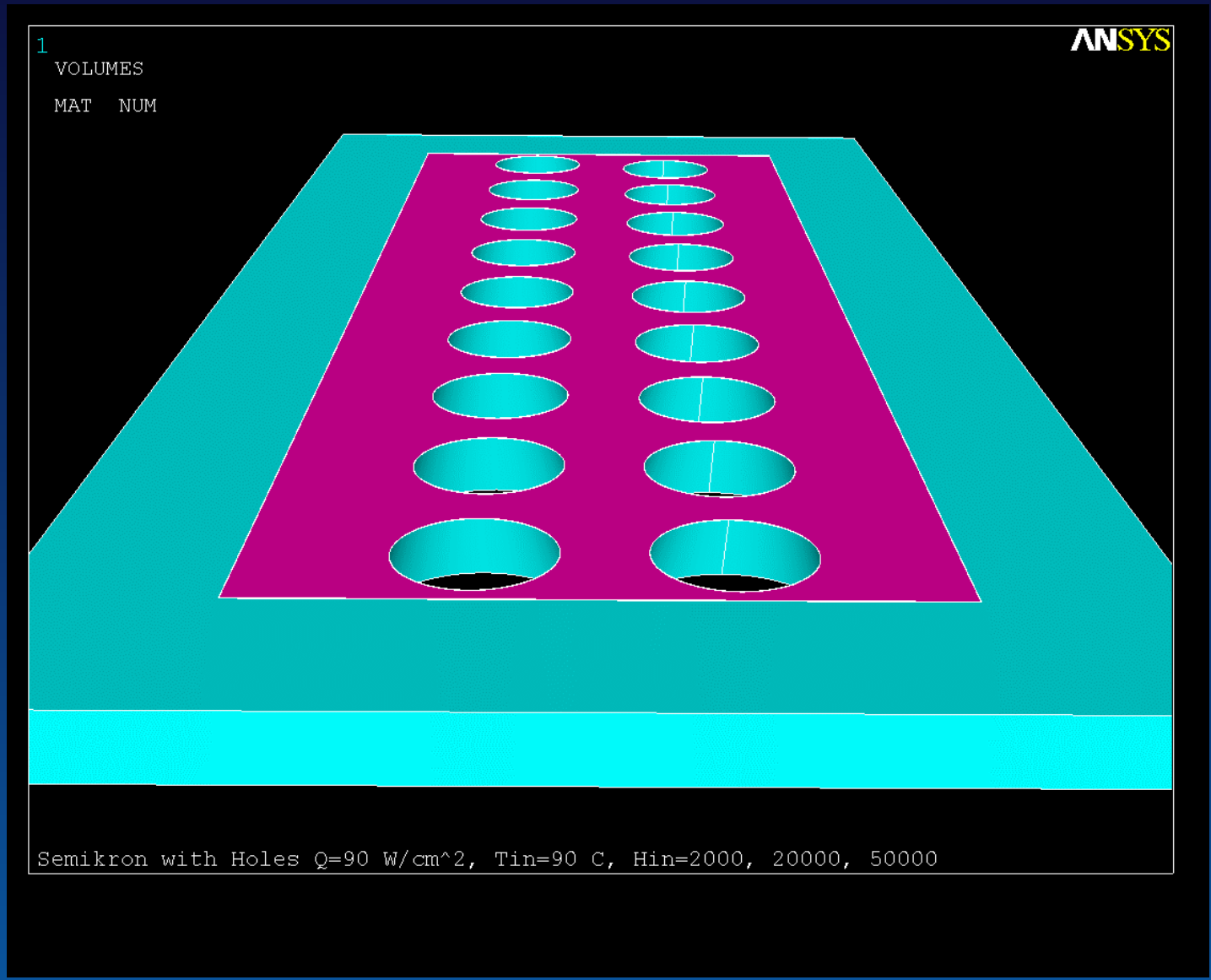
Case A : Solid Spreader Plate

Case B : Spreader Plate with Square Holes

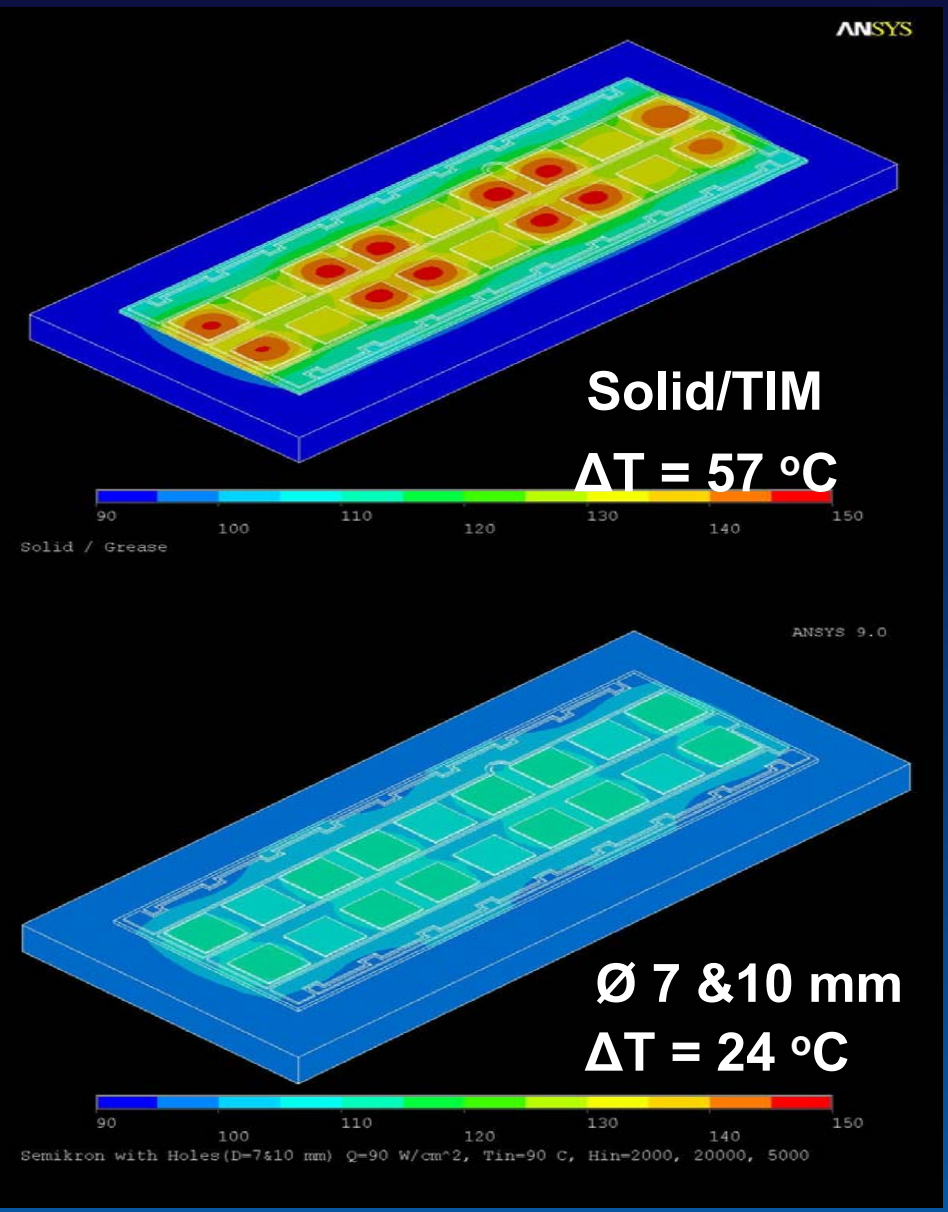
Proposed Low Thermal Resistance IGBT Structure

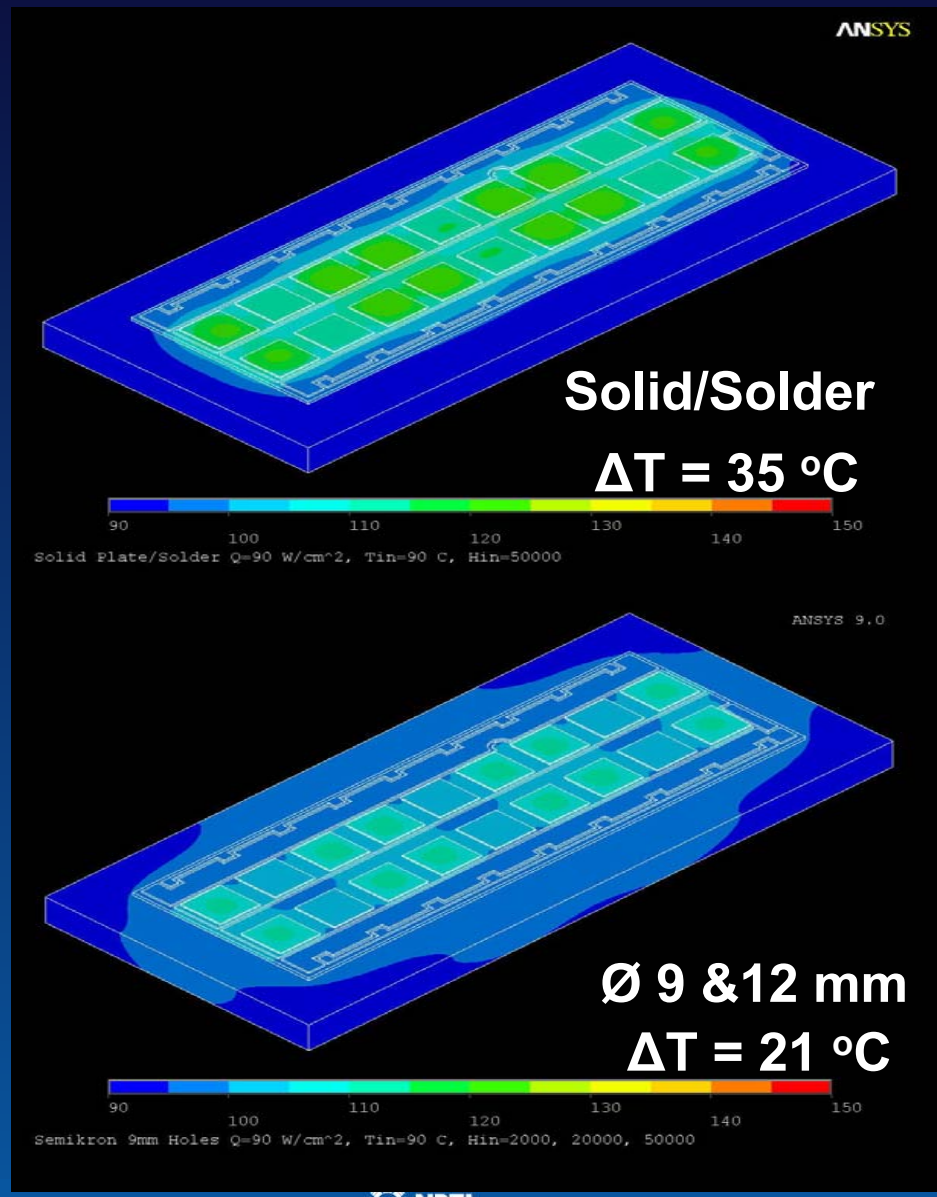
Two cut thru hole sizes were tested:

Ø9 &12
Ø7 &10



Max Temperature Comparison





What NREL Can Offer

- Intellectual Property
- Facilities and skills
  - Modeling capabilities
  - Test facilities
  - Expertise
- Collaborate with Industry
- Extensive relationships with the auto industry
- Hybrid vehicle technology

The Value Proposition

- **Flexible design approach**

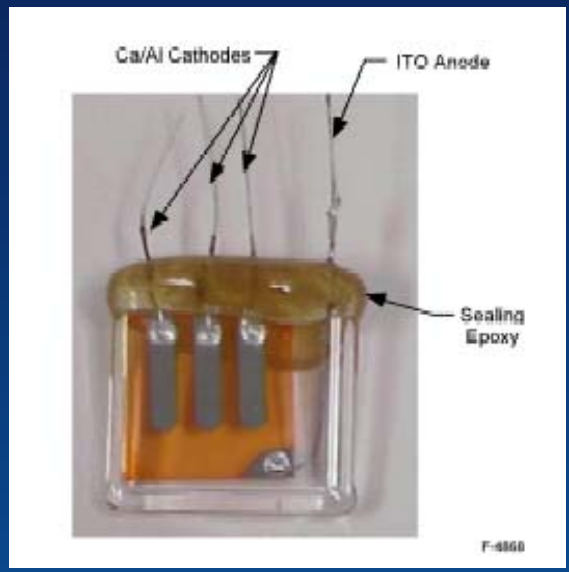
- **Large, rapidly growing markets, multiple applications**
  - **Transportation**
  - **Hard drives**
  - **Data storage**
  - **Electronic products**

- **An area of continuing research**

- **Leveraging NREL resources**
  - **Our people**
  - **Our expertise**
  - **Facilities**
  - **Industry relationships.**

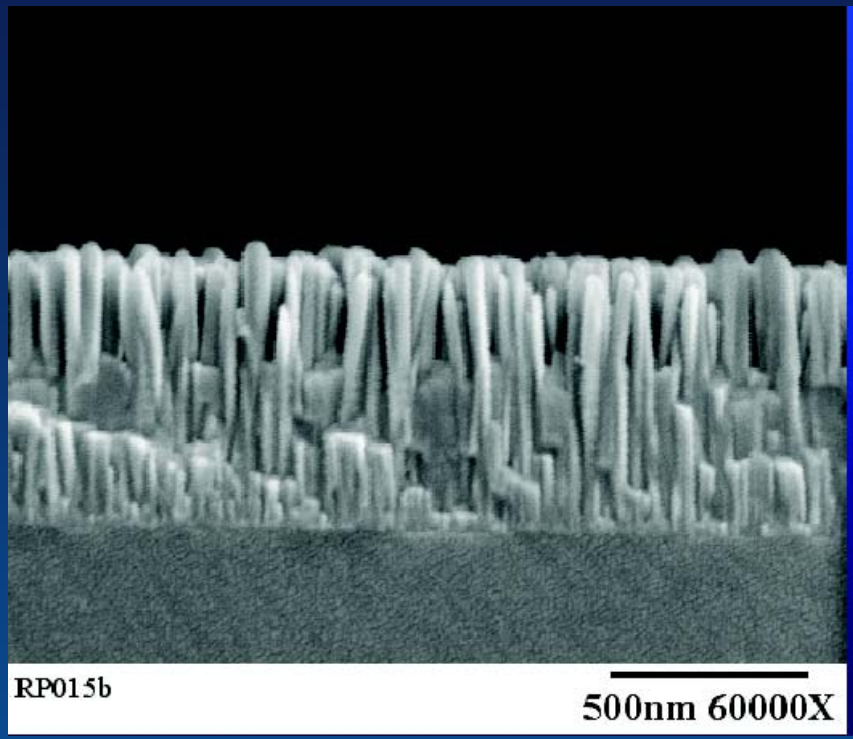
NREL Nanoceramic Nanofibers

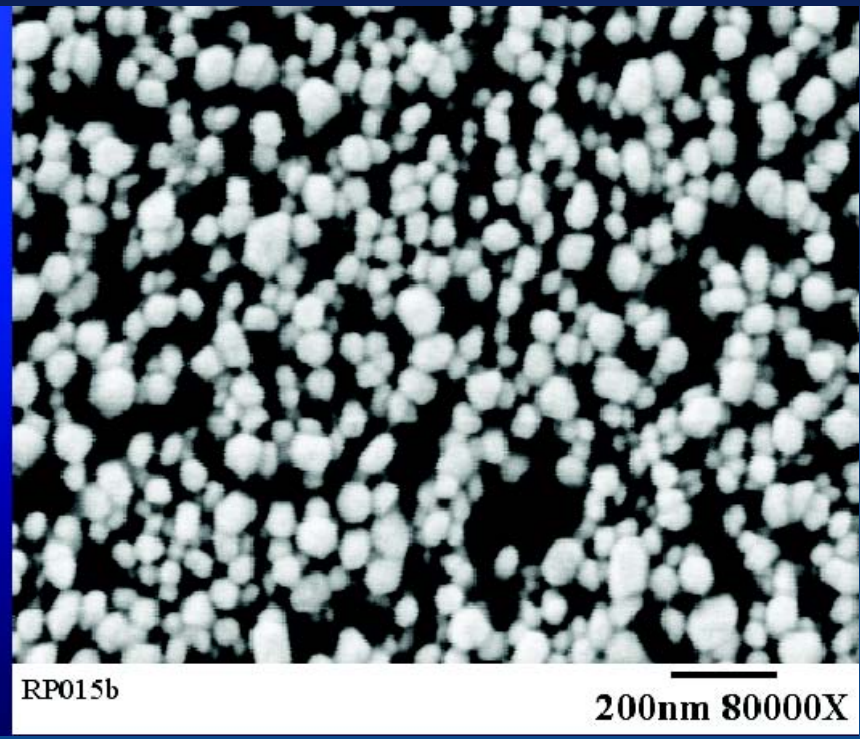
A Platform Technology



Nanoceramic Nanofibers

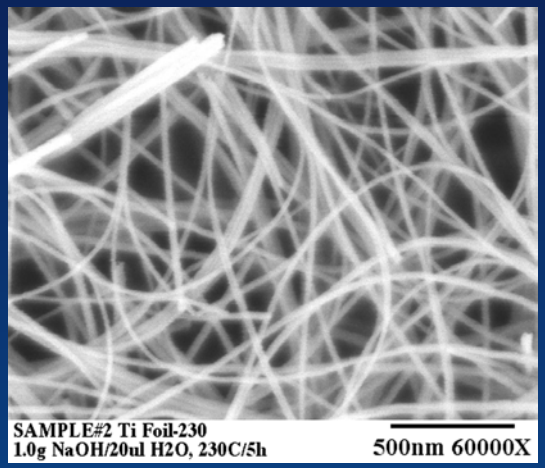
AlO(OH) nanofibers - R&D100 award winner



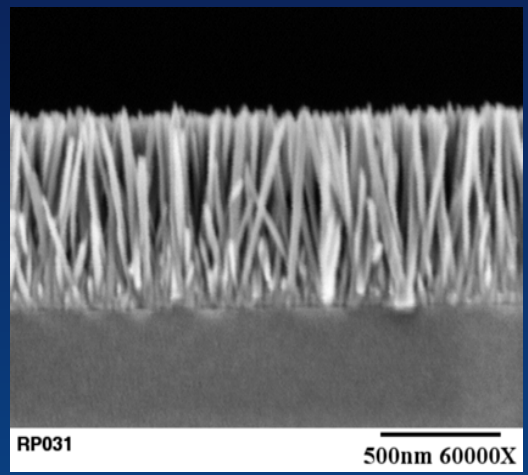


Multiple Substrates and Configurations

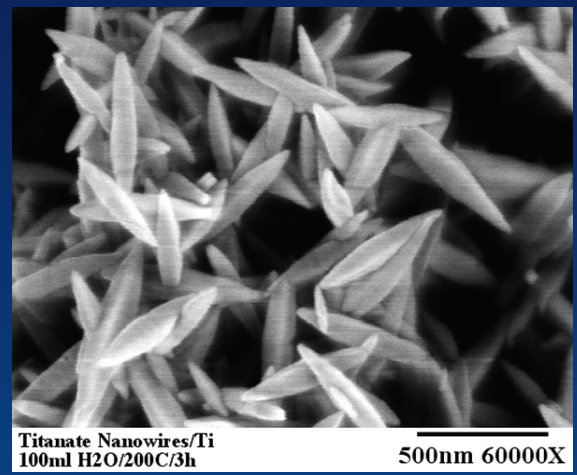
A variety of substrates can be used to produce a multitude of products with different morphologies and properties



Sodium titanate nanowires



ZnO "nanocarpet"



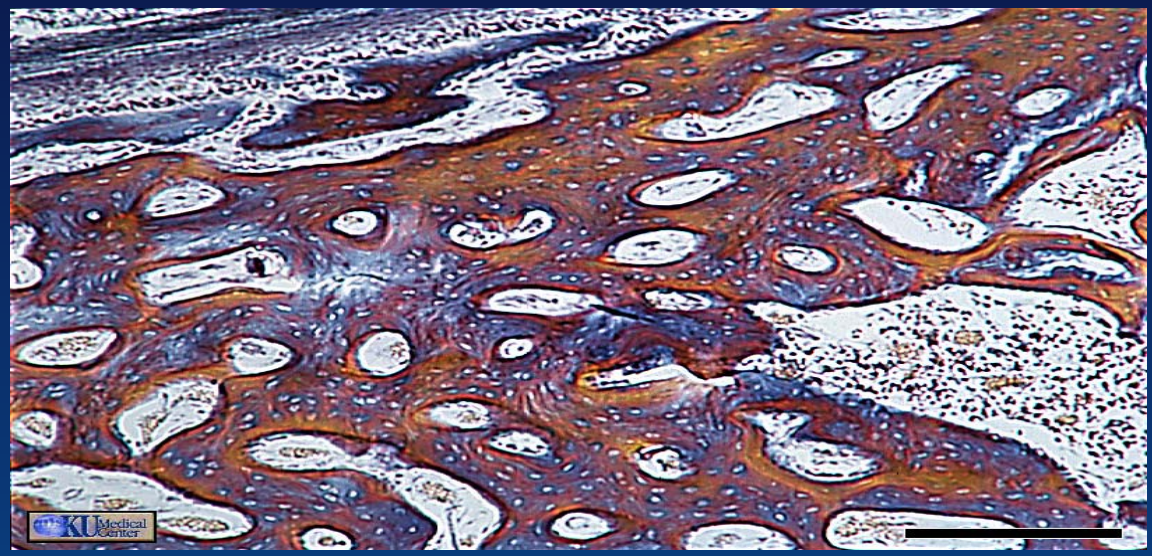
TiO2 nanorods

Worldwide Water Filtration Market

$Million-$Billion Market

Biotechnology Applications

Scaffold for Bone Cell Growth

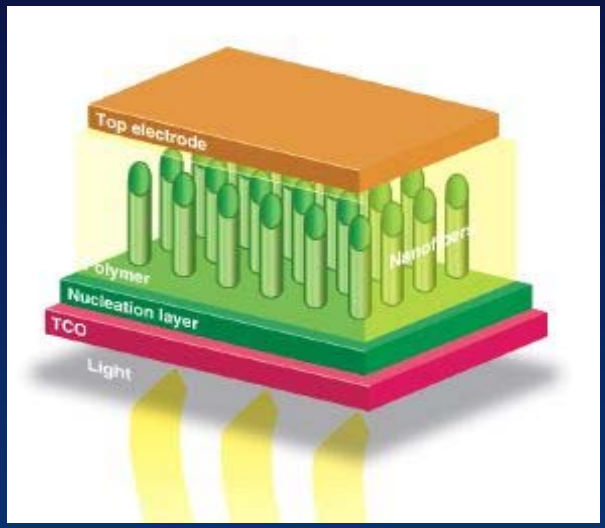


Solid Support for Catalysts

(Nanofibers on macrofibers)

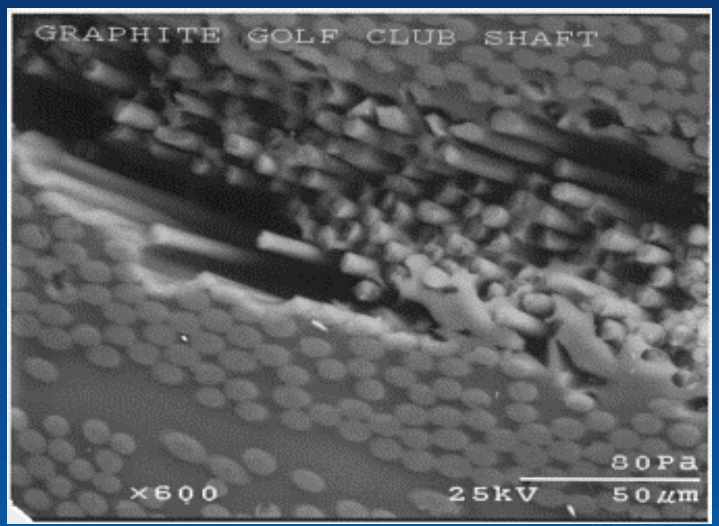
Separation/ Purification Media

Composite Applications



Solar Cell Market = $3-$3.5 Billion

35% annual growth



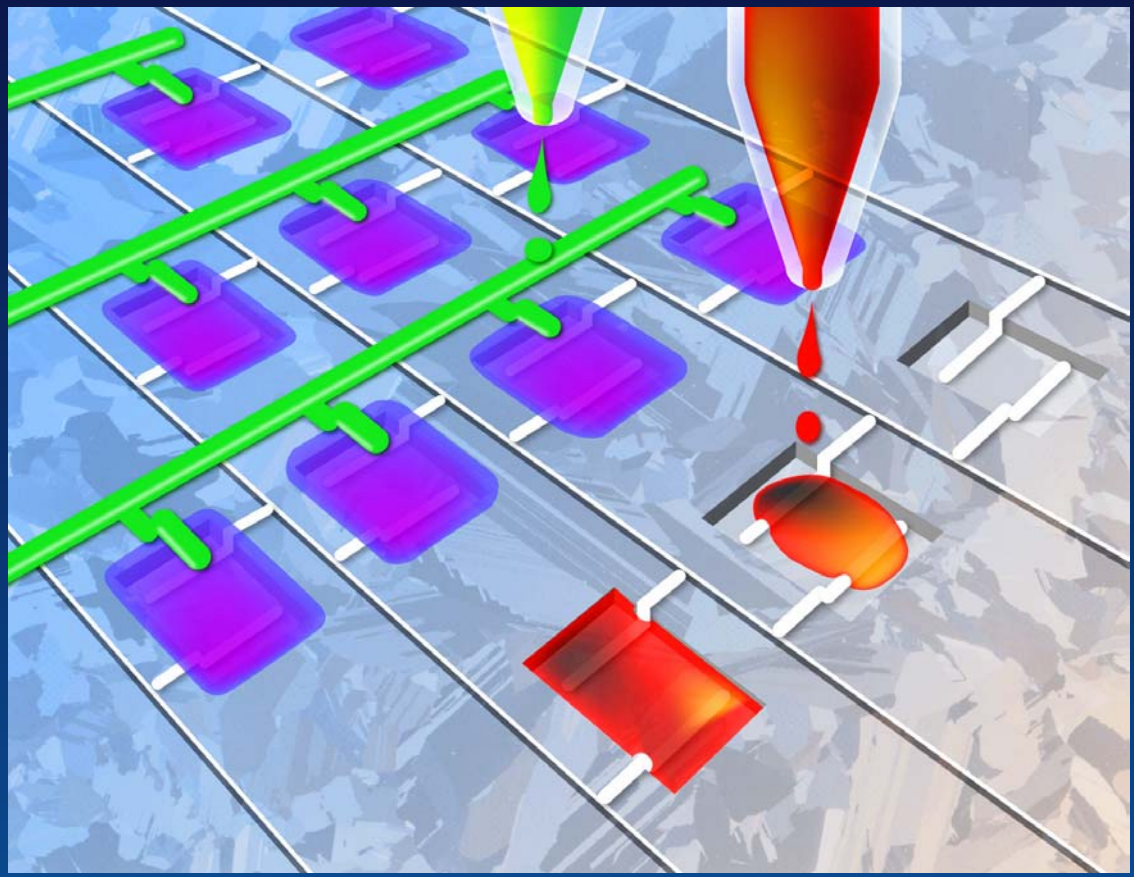
Structural Composites

$Billion Worldwide Market

Value Proposition

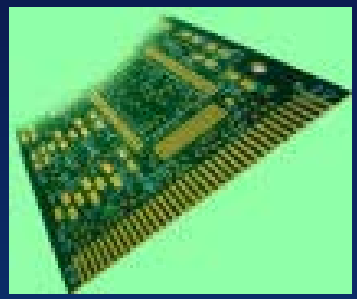
- Platform technology, multiple applications
  - Filtration
  - PV
  - Biotech
  - Composite materials
- Inexpensive to make
- Scaleable manufacturing
- Low capital investment
- Water Filtration on the market with in two years
- Tailored to meet specific applications
- Markets are large and rapidly growing
  - PV market growing at 35%/yr

Inkjet Printing for Electronic Circuits



Applications for Inkjet-Printed Metal Conductors (Ag,Cu)

PV



Printed Circuit Boards

Displays and Touch Screens

Flexible Electronics

Inkjet Printing Vs The Competition

Cheaper – Faster - Better

- **Lower Capital Investment for Processing**
- **Lower Processing costs, materials waste**
- **Green technology, no photolithography**
- **Platform Technology - Dramatic Application and Material Flexibility**
- **Fast /easy prototyping capability**

Inkjet-Printing as a Direct-Write Deposition Approach: A new Paradigm

Solar Cell Market

- Market Dynamics
  - –35% annual growth
  - –$.10/watt for metalization → 60% savings
- In 2008 savings could be about $180M (market for metallization will be $300M+) for Si Solar cells
  - –Thinner Si solar cells will require non-contact (Inkjet) technology
- Inkjet will play an increasingly larger role in next generation solar cells (e.g. CdTe, CIS, and organic)

Most solar cells use Si and the screen process now

Organic Light Emitting Diode Macro Market Information

- OLED market to grow from $91M.(02), $215M (03), to $3.1B(07) – Gale and UDC market analysis
- New Markets being created at an accelerated pace

Packaging

Flat Panels

RFID tags

Organic Solar Cells

Cell Phones

Luggage Tags

Computerized Clothing

NREL Achievements with inkjet printed Materials and Devices:

Cu – is a major Opportunity vs AL

- Ag grids for Si solar cells
- Ag grids on glass for displays
- Cu grids on glass, Printed Circuit Board, metal
- Transparent Conducting Oxides: ITO, SnO, ZnO, combinatorial libraries of In-Zn-O
- High dielectric constant oxides: BaSrTiO3
- Ferroelectric capacitors: dielectric+metal contacts
  - Tunable antennas

The Opportunity: The Deal and Value Proposition

- **Platform technology**
- **Faster, Cheaper, Better than current technologies**
- **License(s) on inks and processes that enable a broad spectrum of new applications and products**
- **NREL opto-electronic process and materials expertise and facilities to help industry**
  - **Incorporate this technology into their products and processes**
  - **Improve profits and market position**

Indoor Air Quality (IAQ) Sector

- Drivers: electric power demand, energy efficiency, indoor comfort and air quality
- Typical Customers: industrial, institutional, commercial, and ultimately residential
- Key Technologies:
dual-use desiccant dehumidifier/air cleaner

The Problem

- The challenges:
  - Fully utilize waste heat from onsite power generation
  - Provide adequate fresh air to buildings with cost-effective humidity and contaminant control
  - Eliminate maintenance issues of wet scrubbers

- Past approaches:
  - Water heating, absorption cooling
  - Electrostatic precipitators, charged filters, plasma filters, HEPA/carbon filters, wet scrubbers

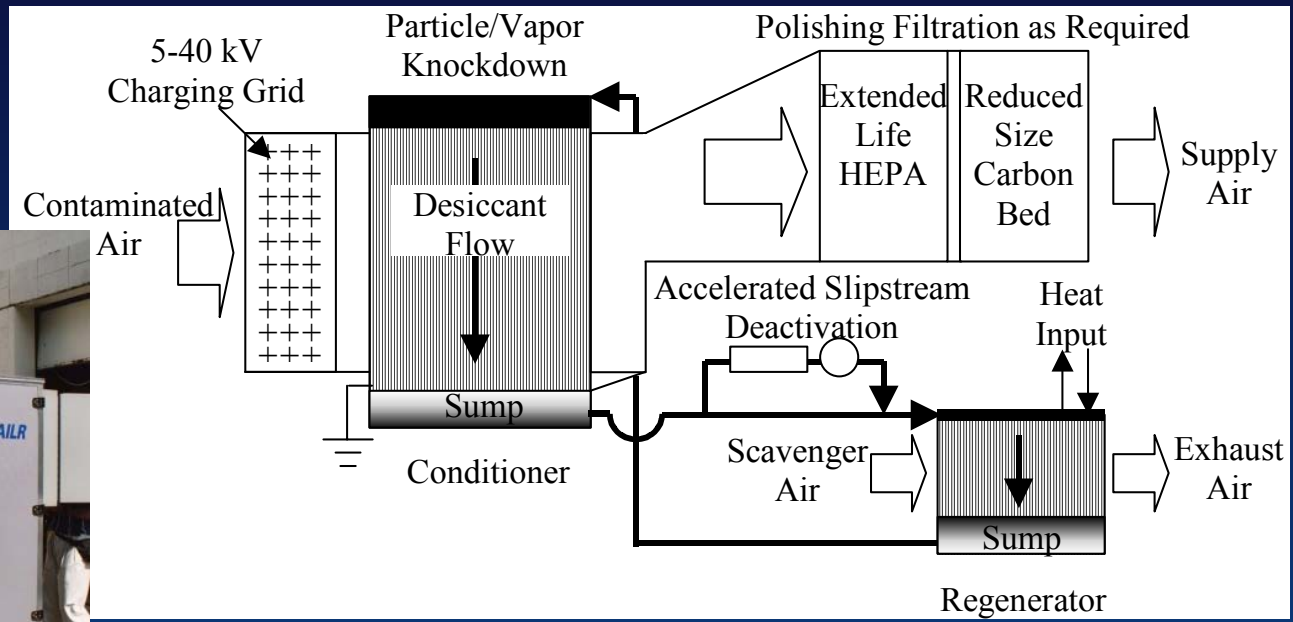
Solutions

- New approaches: self-cleaning, low-maintenance, thermally regenerated liquid desiccant air conditioner
- Benefits of this technology:
  - Double the fuel/emissions efficiency of onsite power
  - Enable enhanced ventilation rates while efficiently controlling humidity and contaminants
  - Regenerative allergen/VOC removal at a fraction of the energy, maintenance, and first cost of HEPA/carbon

The Liquid Desiccant Approach

- Provides continuous benefits of cooling, humidity control, and VOC/allergen control
- Cost-effective and durable HVAC technology
- Patented low-maintenance, zero-entrainment commercial conditioner
- Excellent for all waste heat applications
  - –Low temperature regeneration – engine coolant, PEM fuel cells
  - –Distributed conditioning – centralized regeneration
- Self-cleaning aerosol and particulate air filter capability with biocidal and VOC deactivation potential
- Proven superior in size, cost, maintenance, and efficiency

Liquid Desiccant Technology



The Value Proposition

- **Smaller and lighter: 2,000lb vs. 6,000lb**
- **Lower electric demand: 0.2 kW vs. 1.1 kW per ton**
- **Provides humidity control and avoids wasteful reheat**
- **Low maintenance, Homeland Security applications**

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